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Auditory Recall In Normal Children And Children With A Diagnosis Of Central Auditory Processing Disorder

Kara J. Nunziato

AUDITORY RECALL IN NORMAL CHILDREN AND CHILDREN WITH A DIAGNOSIS OF CENTRAL AUDITORY PROCESSING DISORDER

by

Kara Jo Nunziato
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The thesis, submitted by Kara Jo Nunziato in partial fulfillment of the requirements for the Degree of Masters of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

John P. Madden
Chairperson

Committee Member

SRobinson
Committee Member

This thesis is being submitted by the appointed advisory committee as having met all the requirements of the Graduate School at the University of North Dakota and is here by approved.

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To My Parents, Michael and Julie Nunziato

ABSTRACT

The purpose of this study was to investigate the differences in level of performance on auditory memory tasks between individuals with and without a diagnosis of Central Auditory Processing Disorder (CAPD). The study was also designed to examine the differences in performance among different auditory memory tasks. A total of ten participants were recruited for the study. Five typically developing individuals served in the control group and five individuals with a clinical diagnosis of CAPD served in the experimental group. Results from the study indicated that individuals with a diagnosis of CAPD performed significantly lower than the control group on the sentence recall tasks. Findings also suggested that digits were easier to recall than words in both groups. In conclusion, auditory memory continues to be a treatment target for individuals with CAPD. Additional research is needed in order to better treat individuals with a diagnosis of CAPD.

CHAPTER I

INTRODUCTION

The American Academy of Audiology (2010) defines Central Auditory Processing Disorder (CAPD) as difficulty in the perceptual processing of auditory information within the Central Nervous System (CNS). CAPD manifests itself in an inability to effectively and efficiently use auditory information. Individuals with a diagnosis of CAPD demonstrate dysfunction in the auditory processes involved in attending to, discriminating, recognizing, associating, remembering, comprehending, and recalling auditory information. Children with a diagnosis of CAPD are at risk of becoming learning disabled, as information is almost always presented auditorily in the classroom. When auditory information is presented via a degraded acoustic or in the presence of a competing signal, individuals with CAPD have difficulty attending to and processing relevant stimuli, learning language for comprehension and production, and recalling auditory information. Academic skills such as reading, writing, spelling, following directions, understanding and using vocabulary words, and even mathematics are negatively affected in children with CAPD. Because academic success relies on acquiring these skills, children with a diagnosis of CAPD have difficulty adjusting to curriculum changes that occur around the time of the third grade as skills focus on "reading to learn" rather than "learning to read."

Researchers acknowledge that given the complexities of the Central Auditory Nervous System (CANS), other areas, such as memory, language, and attention, are possibly impacted by CAPD (AAA, 2010; Gillet, 1993). Auditory memory is frequently a treatment target for individuals with CAPD, yet there currently is little research that specifically compares if differences in auditory memory abilities in children with and without CAPD exist. Therefore, the purpose of this study is to determine whether the auditory recall abilities of typically developing children differ from those of children with a diagnosis of CAPD. The study is designed to compare memory abilities in these groups by testing a variety of levels of auditory memory. This study specifically examines the difference between the recall of digits, words with and without a semantic relationship, and sentences. Because auditory memory interacts with both short- and long-term memory, this study will likewise consider the relationship between the use of solely short-term memory in auditory digit and word recall tasks, as well as the effects of semantic memory in the auditory recall of sentences and word lists that contain a semantic relationship.

CHAPTER II

REVIEW OF LITERATURE

Central Auditory Processing

CAP is the process by which the Central Auditory Nervous System (CANS) effectively and efficiently uses auditory information (ASAH, 2005). Auditory activation and processing across neural networks appears to happen instantaneously, but in actuality occurs over a short period of time (Chermack and Musiek, 1997; Sloan, 1986). Within this time period, sounds are transformed, coded, recoded, and processed before becoming a conscious experience for the listener (Sloan, 1986).

The CAP comprises the following phenomena: sound localization and lateralization; temporal aspects of audition; and the integration, discrimination, ordering, and masking of auditory stimuli in the presence and absence of competing or degraded acoustic signals (ASHA, 2005; Bellis, 2003).Tasks such as decoding, perception, recognition, and interpretation of an auditory message involve the integration of CAP with other overlapping sensory and higher-order brain structures and systems of the CANS (Bellis, 2003).

Brain structures involved in CAP include auditory pathways and nuclei within the brainstem, subcortical structures, cortical auditory structures, and the corpus callosum. Analysis of acoustic signals is refined and organized as the stimuli travel from the auditory pathways and nuclei in the brainstem to the cortical auditory structures of the brain. In summary, auditory perception is the product of basic and higher-level functions of the central auditory processes (Sloan, 1986).

Top-down and Bottom-up Processing

Bottom-up processing is a data-driven process initiated via stimulation of sensory receptors and is critical in identifying stimuli within one's environment. Following stimulation of the sensory receptors, information is sent to various areas of the brain for processing (Goldstein, 2008). Bottom-up processing cannot function independently but must interact with top-down processing functions. Top-down processing is a conceptually- or schema-driven process that influences one's perception of stimuli based on previous knowledge from a prior experience. An example of top-down processing is provided by Palmer (1975). Individuals in Palmer's study were presented with a contextual scene (i.e. kitchen counter with knife, cheese, butter, and cutting board) for a short period of time. Following this, individuals were briefly flashed three target pictures. The first target was appropriate (i.e. a loaf of bread), the second was inappropriate (i.e. a drum), and the third was misleading for the scene (i.e. a mailbox of similar shape to the loaf of bread). Based on the use of prior knowledge (i.e. the contextual scene), individuals were able to identify the appropriate item 83% of the time, while only identifying the inappropriate item 50% of the time, and the misleading item 40% of the time. Results from Palmer's study demonstrate the effect of top-down processing in the identification of sensory information (Goldstein, 2008).

In order to attend to stimuli, access memories to retrieve previous information, and use cognitive abilities to perceive and associate sensory stimuli, CAP involves the interaction of both bottom-up and top-down processing. CAP, like bottom-up and top-down processing, is not a unidirectional process. Rather, CAP involves a backward, forward, and lateral distribution of connections across a network (Bellis, 2003). CAP requires the interaction and overlap of bottom-up and top-down processing. Bottom-up processing is the initial process of CAP that occurs within the auditory system prior to the higher order operations of top-down processing (i.e. decoding and interpretation) (Bellis, 2003). Top-down factors, such as attention, memory, and linguistic competence influence bottom-up processing. In listening situations, top-down processing accesses one's prior knowledge and current expectations of the situation to allow an individual a meaningful experience.

According to Chermack and Musiek (1997), top-down processing is more significant when auditory information is presented with competing or degraded acoustic signals. That is, when an individual is processing auditory information in a noisy environment, top-down processing allows one to decode and interpret an auditory signal. Therefore, individuals with a Central Auditory Processing Disorder (CAPD) may have a breakdown in the area of bottom-up and top-down processing of auditory information. This breakdown is the result of difficulties with processes involved in recognizing and interpreting complex auditory stimuli in the presence of competing noise.

Central Auditory Processing Disorder

CAP, as previously mentioned, is a complex activity that refers to the ability of the CANS to effectively and efficiently use auditory information (ASAH, 2005). Essentially, CAP is "what we do with what we hear" (Lansky & Katz, 1983). CAPD is a range of hearing difficulties within several listening domains (i.e. temporal, monaural, binaural acoustic information, and discrimination) in the absence of a peripheral hearing loss (Lansky & Katz, 1983; Schow and Nerbone, 2007). More specifically, The American Academy of Audiology (2010) defines CAPD as "difficulties in the perceptual processing of auditory information in the Central Nervous System (CNS) and the neurobiological activity that underlies that processing and gives rise to the electrophysiological auditory potential" (p. 5). Individuals with a diagnosis of CAPD have difficulty processing auditory sensory information from the peripheral mechanism (i.e. bottom-up processing). Disruptions within the central auditory process interfere with one's ability to effectively and efficiently perceive an auditory signal (Sloan, 1986). Individuals demonstrating CAPD typically have difficulties within the basic and higher-level functions of the central auditory processes.

Central Auditory Processes and CAPD Characteristics

CAP consists of six common auditory processes: auditory figure-ground, auditory discrimination, auditory perception, auditory association, auditory synthesis, and auditory memory. The development of these auditory processes appears to be related to the normal acquisition of academic skills (Gillet, 1993). Language development and academic skills such as comprehension, communication, spelling, writing, reading, and even mathematic skills rely on the functions of the auditory modality and processes (Gillet, 1993). Understanding the separate auditory processes is necessary when discussing the difficulties in language and academic skills observed in individuals with a diagnosis of CAPD.

Auditory Figure-Ground

The ability to perceive relevant auditory stimuli in the presence of competing acoustic signals relies on figure-ground processing. Everyday environments consist of multiple sounds varying in pitch, intensity, and meaning (Gillet, 1993). In auditory situations, attending, listening, and comprehending all sounds at one given time is impossible and unnecessary because all sounds within a particular setting are not of equal importance. Therefore, auditory figure-ground processing focuses on the important signal (i.e. “figure”) and “backgrounds” the competing noise (i.e. “ground”) (Gillet, 1993).

Figure-ground processing regulates the multiple sources of acoustic stimuli within an environment by focusing attention on the focal acoustic signal. Auditory figure-ground is directly related to skills such as listening and both selective and sustained attention.

Individuals with auditory figure-ground problems typically have difficulty differentiating which stimulus is essential and which stimuli need to be filtered out (Gillet, 1993). Individuals within a classroom setting may be severely affected when an essential message is presented in the presence of a competing acoustic signal. Individuals may appear to be inattentive, lost, and socially inappropriate as they are unable to filter out irrelevant auditory information (Gillet, 1993).

Auditory Discrimination

The ability to differentiate similarities and differences in sounds is referred to as auditory discrimination. Auditory discrimination is not related to sensory acuity; rather, it is related to the ability to selectively hear beginning, middle, and ending sounds in words and words in sentences (Gillet, 1993). Speech perception relies on the auditory discrimination process to differentiate common words that differ by only one phoneme (i.e. /p/ and /b/ in pat and bat). The ability to discriminate differences in isolated sounds and words is not only important for speech perception but also for discriminating environmental sounds and verbal emotions conveyed in conversations (Gillet, 1993).

Auditory discrimination is involved in the most basic academic skills, such as learning phonemic structures for articulation of speech, understanding different meanings of similar sounding words (i.e. cat and cap), and attaching meaning to printed symbols when reading (Gillet, 1993).

Individuals with CAPD can have various degrees of auditory discrimination problems, as, for example, an individual may have more difficulty with fine but not gross auditory differences (Gillet, 1993). Consequently, individuals typically have difficulty rhyming words and selectively hear beginning, middle, and ending sounds, which is fundamental to the construction of “word families” when reading (Gillet, 1993). Auditory discrimination deficits may affect an individual's ability to correctly attach meaning to printed symbols, therefore hindering spelling and reading (Gillet, 1993).

Auditory Perception

Auditory perception is the process by which one receives an auditory signal and then translates the signal into understood sounds and words. Auditory perception has a significant role in the development of many skills. Skills involved in basic communication, social relationships, and conceptual development, as well as reading skills, processing verbal information, and responding appropriately in an environment all require the ability to perceive auditory information (Gillet, 1993). Other significant skills, such as attaching meaning to words, understanding and following directions, comprehending, and understanding whole meanings of discussions, all rely on one’s ability to perceive an incoming auditory signal. In summary, auditory perception is a higher-level process critical in the development of understanding or applying meaning to auditory stimuli, verbal communication, and interpersonal relationships (Gillet, 1993).

Individuals demonstrating difficulties with auditory perception, depending on the severity of the auditory perception problem, exhibit various difficulties in learning language and using language to learn (Gillet, 1993). Individuals may have difficulty in one or all of the following skills: following directions, understanding meaning from class/group discussions, understanding relationships of words, and comprehending questions or information presented auditorily (Gillet, 1993). These individuals typically have poorer receptive vocabulary skills than expressive vocabulary skills. They typically demonstrate difficulty repeating oral instructions and lose the general topic of oral class discussions. Such individuals also demonstrate difficulty with the understanding of multiple-meaning words, concepts (i.e. quantitative, direction, and spatial), and words that convey emotion (i.e. sad, happy, upset). These individuals demonstrate severe difficulty learning in the classroom, as novel and familiar information is almost always presented auditorily.

Auditory Association

Auditory association is the ability to draw relationships from spoken language, quickly access and manipulate internal vocabulary, and organize a meaningful verbal response (Gillet, 1993). Auditory associations allow an individual to retain words for spontaneous speech, complete simple sentences, and respond to brainteasers such as riddles. Academically, classrooms frequently require verbal responses from students. Therefore, auditory association processing is critical for academic participation and success.

Individuals with auditory association difficulties typically do not respond immediately to verbal questions; rather, they require time to process or think about the meaning of the presented auditory stimuli (Gillet, 1993). The ability to hold multiple verbally-presented concepts and consider their relationships is affected in individuals with auditory association difficulties. Difficulties with auditory associations may be present in an individual's ability to draw meaning from what is heard and make generalizations. Detecting absurdities and comprehending abstract concepts can be difficult for individuals with CAPD. Therefore, classroom work for these individuals is difficult, as they cannot keep up with the rate at which complex information is presented.

Auditory Closure

Auditory closure involves the ability to blend sounds and syllables together to form and produce a word (Gillet, 1993). The ability to break spoken words up into separate sound segments also relies on auditory closure processing. Auditory closure relies on factors such as the frequency with which an expression has been heard, the number of choices presented in a particular expression, and the length of an expression (Gillet, 1993). The ability to blend and sequence sounds and syllables into words is necessary for academic skills such as reading and writing (Gillet, 1993). Essentially, the ability to pronounce words and sound out words for spelling, reading, and writing relies on an individual's ability to integrate sounds.

Individuals with auditory closure difficulties commonly misspell words by leaving out syllables or creatively spelling a word the way it is perceived. When reading, individuals typically break up words into sound segments but have difficulty blending them together smoothly to pronounce a word. For multisyllabic words, individuals may only pronounce the first one or two syllables and then guess on the last segments of the word (Gillet, 1993). Overall, difficulties in auditory closure affect an individual's ability to break down words into syllables and sounds, read and comprehend material, and perceive the parts as they are related to the whole word. These individuals are slow, over-analytical readers as they typically fixate on individual letters and sounds, not the whole word and its meaning (Gillet, 1993).

Auditory Memory

Auditory memory or auditory recall is defined as the ability to retain and recall information presented via the auditory system. Recognizing familiar tunes, the sound of an airplane, and understanding language are examples of auditory memory (McAdams and Bigand, 1993). For recalling auditory information, short-term memory is heavily influenced by auditory processing abilities. Auditory memory processing and its connection with short-term memory allow individuals to recall information immediately, as well as over a short period of time. Factors such as the length and meaning contained in an auditory message affect auditory recall and short-term memory. For example, auditory memory recall tasks, such as naming, rote, and following directions contain different levels of complexity. The hierarchy of auditory recall generally begins with the naming of concrete objects, naming familiar objects in pictures, recalling numerals, recalling letters, recalling words, and last of all, recalling sentences (Gillet, 1993). When auditory information lacks meaning, such as listing a series of randomly presented numerals, auditory recall ability is limited by the message's length and lack of meaning. In summary, auditory recall abilities vary according to the task (i.e. recalling digits, words, and sentences). Without auditory memory, short- and long-term memory would not accurately retain auditory information. Therefore, auditory memory is heavily involved in learning language and academic information as the auditory modality is of prime importance within school and learning environments.

When discussing and evaluating an individual's auditory recall ability, oral and written outputs, as well as the ability to follow directions, are considered (Gillet, 1993). Individuals with CAPD demonstrate difficulty retaining, recalling, and sequencing auditory information. Deficits in auditory memory affect both immediate and delayed recall of digits, words, sentences, and events in a story. Sequencing difficulty in these individuals may result in the inability to learn and recall everyday items such as the days of the week, seasons, and months of the year (Gillet, 1993). Individuals with CAPD may have difficulty remembering names of people or objects in the classroom and in other familiar environments. The ability to rote count, recite the alphabet, and remember multiplication tables, addresses, and phone numbers is affected in individuals with auditory recall deficits. In the classroom, individuals with CAPD may have difficulty storing the information necessary for developing language, reading, following directions, imitating words, and sentences. In conclusion, all aspects of language are dependent on auditory memory skills. Individuals who have auditory memory deficits may be severely handicapped in a variety of academic, social, and emotional skills (Gillet, 1993).

Memory Stores

The use of both long- and short-term memory is involved in auditory processing. Generally speaking, memory is the global process involved in reproducing or recalling information about stimuli, images, events, ideas, or skills learned and retained via the associative mechanisms (Gillet, 1993; Goldstein, 2008). Memory consists of four major structural features: sensory memory, short-term memory, working-memory, and long-term memory (Goldstein, 2008). In order to maintain short- and long-term memory, sensory memory must occur first.

Sensory Memory

Incoming sensory information constantly bombards one's sensory system. Most sensory information is disregarded as only small amounts of sensory information are attended too. Sensory memory holds all incoming sensory information, usually for a fraction of a second (Goldstein, 2008; Weiten, 2007). Sensory memory then transfers the perceived sensory input to what is called short-term memory.

Short-Term Memory

Short-term memory (STM), generally assessed by various recall tasks, is a limited capacity that maintains unrehearsed sensory information for about 20 seconds (Weiten, 2007). Research conducted by George Miller (1956) suggests that the span of immediate recall is typically "seven plus or minus two" regardless of the unit presented (i.e. letter, digit, or words) (Eysenck, 2001, p. 161). Information can exceed 20 seconds or 5 to 9 units when an individual uses strategies such as chunking or rehearsal processing. Chunking is the process by which an individual groups familiar stimuli into a single unit, while rehearsal processing is the ability to repetitively verbalize or reflect upon information transferred from sensory memory (Goldstein, 2008). Both chunking and rehearsal processing are involved in everyday situations, such as looking up and remembering a phone number in the phonebook. Information held in STM is essentially fragile as any distraction contributes to forgetting (Eysnck, 2001). In order for information to be transferred to the long-term memory store, information is manipulated by working memory.

Working Memory

STM is complex and is often times confused with or characterized as "working memory"; however, STM and working-memory should not be considered as equal (Weiten, 2007). As defined by Baddely (2000), working memory is "the limited capacity system for temporary storage and manipulation of information for complex tasks such as comprehension, learning, and reasoning" (Goldstein, 2008, p. 154). Working memory can be used to predict whether two tasks can be performed simultaneously (Eysenck, 2001). The process of working memory is more advanced than STM. Working memory has been positively related to higher-level cognitive abilities such as reading, comprehension, complex reasoning and even intelligence (Weiten, 2007). Working memory, in comparison to STM, consists of a number of parts. The four components of working memory are the following: phonological loop, visuospatial sketchpad, central executive system, and the episodic buffer (Goldstein, 2008). The central executive system is the most important component of working memory as it active when dealing with cognitive tasks (Eysenck, 2001). The phonological loop and visuospatial sketchpad are activated via the central executive system according to the task at hand (Eysenck, 2001). For example, when dealing with words, the phonological loop is activated and when processing visual/spatial information the visuospatial sketchpad is activated. The episodic buffer binds information in the subsidiary systems and communicates with long-term memory store to create a unitary representation (Goldstein, 2008). While the central executive system activates the appropriate systems (i.e. phonological loop, visuospatial sketchpad, and episodic buffer), each system separately communicates with long-term memory.

Long-Term Memory

In contrast to STM, LTM can hold large amounts of information for long periods of time (hours, days, weeks, months, years, etc.) (Goldstein, 2008). Information held in LTM is durable and can extend for an entire lifetime (Weiten, 2007). LTM can be broken down into two main categories: explicit (declarative) memory and implicit (procedural) memory. Implicit or procedural memory is the unconscious memory of skills. Skills learned via procedural memory typically use objects or body movements (i.e. riding a bike or playing the piano). This unconscious or procedural memory consists of automatic sensory-motor behaviors. Such automatic information and behaviors are "deeply" stored and involve no conscious effort. That is, once learned, behaviors and actions are carried out automatically.

In contrast, explicit or declarative memory refers to the information and skills learned at the conscious level. Eventually, these memories serve as autobiographical events, such as time, place, and association of emotion and other contextual knowledge. Explict or declarative memory can be further categorized into episodic memory and semantic memory (Goldstein, 2008). Semantic and episodic memories are distinguished by the type of information remembered. Episodic memory is associated with the remembrance of personally experienced events or "mental time travel" (Goldstein, 2008). For example, remembering a childhood family vacation involves "self-knowing" or episodic memory. In contrast to episodic memory, semantic memory is the memory of facts or knowledge about the world (Goldstein, 2008). Categorizing, pulling meaning from sentences, detecting word relationships (i.e. acknowledging that cat, bird, and dog are animals), understanding vocabulary, numbers, and concepts involve "knowing" or semantic memory (Goldstein, 2008). Episodic and semantic memory, while different, has obvious connections (Goldstein, 2008). For example, episodic memory of a specific event can be lost, yet semantic memory from a personal event can remain (Goldstein, 2008). That is, when sitting in a high school class and learning factual information, an individual might not remember the specific episodic information of the personal experience, but may be able to remember the information learned during that classroom discussion. Episodic memory can also enhance semantic memories (Goldstein, 2008). That is, when semantic information is linked with a personal experience, facts and prior knowledge may be more distinct and meaningful.

Information held in LTM's explicit and implicit memory is accessed by working memory, which in return affects STM abilities. That is, previously learned information stored in LTM will enhance STM's ability to hold incoming information, as it is familiar. Overall, LTM works closely with working memory in order to keep track of our ongoing experiences. LTM is essentially an archive that is referred to when remembering past events and semantic information (Goldstein, 2007).

Memory and CAP

Memory, like CAP, has been investigated extensively by various researchers. Despite the overlapping areas of CAP and memory, there is little research to date that examines their relationship. Research suggests that STM is related to the storage of phonological codes while LTM is related to the storage of semantic codes (Purser and Jarrold, 2010). When discussing CAP and auditory memory, auditory recall tasks typically utilize STM abilities; however, LTM may be more involved when discussing the recall of items with semantic relationships, for example, names, phone numbers, and addresses (Weiten, 2007; Goldstein, 2008). In conclusion, little is known about the relationship and effect CAPD has on memory abilities or vice versa; however, research does acknowledge that individuals with CAPD have deficits in memory along with other cognitive areas (Bellis, 2003).

Summary of CAPD

CAPD may stem from a variety of deficits within the CANS. Therefore, characteristics or impairments observed in individuals with CAPD are diverse. Children with CAPD appear to be inattentive, forgetful, impatient, or at times socially inappropriate (Schow and Nerbone, 2007). Individuals with CAPD behave as though a peripheral hearing loss is present and demonstrate difficulties beyond listening and comprehending. When assessed with speech-language and psychoeducational tests, these individuals demonstrate significant scatter across subtests, with weaknesses evident within the areas of auditory processing (Bellis, 2003). Individuals appear to have short attention spans and become fatigued with complex listening situations (i.e. lectures, fast speech, or conversation in noisy environments). Listening difficulties become evident and problematic around the third grade, when listening situations become less direct and more complex (Schow and Nerbonne, 2007). Typically, individuals with CAPD will exhibit normal to high IQ scores, yet demonstrate difficulty in the area of verbal language skills (Bellis, 2003). Often individuals with CAPD struggle academically, withdraw into themselves, and refuse to participate, or respond inappropriately, in class discussions (Bellis, 2003; Shipley and McAfee, 2009). Short-term and long-term memory skills such as recalling the alphabet, counting, and labeling the days of the week and months of the year are often affected in this population. Research has demonstrated that school-aged individuals with CAPD exhibit some kind of a learning disability. CAPD difficulties typically manifest in attending, reading, spelling, musical/singing ability, and following complex verbal directions or commands (ASHA, Guidelines, 2005). Symptoms commonly associated with CAPD overlap with characteristics observed in other sensory and cognitive deficits (i.e. attention deficit hyperactivity disorder, dyslexia, autism spectrum disorder, learning disabled and specific language impairment).

Statement of the Problem

In both children and adults, memory skills are critical in the learning process as memory skills (i.e. short- and long-term) are related to academic success and achievement. Individuals with a diagnosis of Central Auditory Processing Disorder (CAPD) typically demonstrate difficulties with the some or all of the central auditory processes. It is assumed that auditory memory is affected in this population; however, no one has directly investigated the differences in auditory recall abilities in both typically developing individuals and individuals with CAPD.

The purpose of this study is to compare the auditory recall abilities of typically developing individuals with those of individuals with CAPD. The study will examine the ability to recall word lists with and without a semantic relationship, digit lists (forwards and backwards), and sentences varying in length and complexity. This study is designed to answer the following research questions:

Research Questions

1. Is there a significant difference in performance on recall tasks between the CAPD group and control group?
2. Is there a difference in performance among the different auditory memory tasks within the CAPD group or the control group?

CHAPTER III

METHODOLOGY

Overview

The purpose of this study was to investigate the differences in level of performance on auditory memory tasks between individuals with and without a diagnosis of Central Auditory Processing Disorder (CAPD). These differences were examined at the word, digit, and sentence levels. Testing took place in a single, two-part session. In the first portion of the session, the participants were administered a battery of CAPD screening tools to confirm that the individuals within the control group had no presence of CAPD. In the second portion of the session, the participants were administered auditory memory tests that assessed auditory memory recall abilities.

Participants

The participants were recruited from the Grand Forks Public School system via letters sent home to the parents of children with and without a diagnosis of CAPD between the ages of 8 and 12 years. Five of the participants recruited had a diagnosis of CAPD and served as the experimental group, and five typically developing participants served as the control group. Individuals received 25 dollars for participating in the study.

Assessment Instruments

Central Auditory Tests

A public school speech-language pathologist (SLP) and a University of North Dakota clinical supervisor, who was also an SLP, assisted the primary investigator in compiling a battery of auditory processing tests routinely used to evaluate children's auditory processing abilities. The participants in the study were assessed using two subtests from the *Multiple Auditory Processing Assessment* (MAPA; Schow et. al., 2007) and three subtests from the *Test for Auditory Processing Disorders in Children-3:C* (SCAN-3:C; Keith, 2009). The MAPA subtests assessed skills associated with the temporal and binaural domains of central auditory processing (Schow et. al., 2007). Subtests selected from the MAPA included the Pitch Pattern Test and Dichotic Digits Test. The three subtests from the SCAN-3:C assessed skills associated with the binaural and monaural domains of central auditory processing (Keith, 2009). Subtests selected from the SCAN-3:C included the Filtered Word, Auditory Figure-Ground, and Competing Word subtests.

Auditory Recall Tests

Two subtests from the *Clinical Evaluation of Language Fundamentals Fourth Edition* (CELF-4; Semel, Wiig, & Wayne, 2003) and two word lists commonly used to assess in assessing auditory recall abilities were used to assess auditory memory. The CELF-4 subtests assessed backward and forward digit repetition, and sentence imitation skills. Two sets of word lists with items of various lengths were created to assess word recall. The first set of word lists contained non-related words (e.g., a list containing an item consisting of car, bird, fan). The lists within this set increased in difficulty, as the number of words in each item increased by one in each list (i.e. list one contained two words per item, list two contained three words etc.). The second set of word lists contained lists of items consisting of semantically related words (e.g., an item might contain bat, ball, glove) and increased in length in the same way as the semantically unrelated lists. The sequencing of the auditory recall tests was counterbalanced prior to administration to prevent skewed results due to testing fatigue. The tests are contained in Appendix B.

Assessment Procedures

Central Auditory Tests

The CAPD portion of the testing session occurred in a sound treated room. Prior to the administration of the MAPA and SCAN-3:C, all participants were given a pure-tone hearing screening bilaterally at 20 dB HL at frequencies of 1000, 2000, and 4,000 Hz.

In the MAPA subtests (pitch pattern test and dichotic digits), test instructions and stimuli were presented from a compact disc (CD) played through an audiometer. The Pitch Pattern subtest required participants to listen a sequence of four high (H) or low (L) tones. Participants were asked to repeat the pattern of the tones (e.g., LHHH). In the MAPA Dichotic Digit Test, participants were required to repeat a total of six numbers: three were heard in the right ear and three different numbers were heard in the left ear. Numbers were presented to both ears simultaneously. Individuals were asked to repeat the numbers heard in each ear separately (i.e. starting with the numbers in the right, followed by the numbers heard in the left and vice versa). Individuals were given credit if the numbers were recalled correctly, regardless of the order.

The three SCAN-3:C subtests (auditory figure-ground, filtered words, and competing words) were presented using a recording of assessment instructions and stimuli. In the Filtered Word subtest, participants were presented with stimuli consisting of one-syllable words which were low pass filtered with a cut-off point at 1000Hz.

Participants were required to repeat these muffled stimuli. 2 practice trials and 20 test words were presented to the right ear followed by 2 practice trials and 20 test words to the left ear. In the Auditory Figure-Ground subtest, participants were required to repeat one-syllable words recorded in the presence of a multi-talker speech babble at a +8 dB signal-to-noise ratio, making the stimulus words 8 dB louder than the speech babble. In this test, two words were presented in each trial. In the initial trial, the first word was presented in the right ear, followed by a second word presented in the left ear. This task was then repeated in the opposite order beginning with the left ear followed by the right ear. 2 practice trials and 20 test trials were presented to the right ear followed by 2 practice trials and 20 test trials to the left ear. In the Competing Words subtest, a directed listening task, participants were required to listen to one-syllable word pairs that were presented to the right and left ears simultaneously. Participants were asked to repeat both words in any order (i.e. right ear first or left ear first). 2 practice word pairs and 15 test word pairs were presented. The participant received a break and snack following the MAPA and SCAN-3:C subtests.

Memory Tests

The auditory memory portion of the testing occurred in a therapy room. In the Recalling Sentences subtest of the CELF-4, participants were required to repeat sentences of varying length and complexity. Individuals achieved a score of 3 if a sentence was repeated correctly, a score of 2 if one error occurred, a score of 1 if two or three errors occurred and a score of 0 if four or more errors occurred. In the Number Repetition subtest, participants were required to recall number lists of various lengths (i.e. list one contains two number, list two has three numbers etc.) in both forward and backward sequences. Responses were given one point if the numbers were reported in the correct order.

Two sets of word test lists were created to assess the recall of both non-semantically related and semantically related words. Prior to the administration of the word lists, participants were asked to point to a number of pictures to ensure word familiarity in recall tasks. Participants were required to repeat the words in the order in which they were listed (i.e. dog, moon, chair). Responses were given one point if the list of words was repeated in the correct sequence. Word lists were not repeated upon participant request.

Data Analysis

The data from these tasks was analyzed in two separate analyses. The first analysis considered possible differences within tasks across groups. The second analysis considered possible differences between tasks within groups. The digit recall tasks and sentence recall tasks are subtests of a standardized test and therefore yield both raw and standardized scores. The word recall tasks were created specifically for this study and yield only raw, non-standardized scores. Because the format of the word recall tasks was constructed parallel to that of the digit recall tasks, the raw word recall scores can be compared to the raw digit recall scores. Therefore, all comparisons among digit recall and sentence recall scores involve standardized scores, whereas all comparisons among word recall and digit recall scores involve raw scores.

Descriptive analysis consisted of obtaining measures of central tendency and variances. A repeated measures Analysis of Variance (ANOVA) was conducted to determine whether differences between the groups and between the two types of word lists and digit lists occurred. A univariate general linear model ANOVA was also used to determine if differences between the groups on the sentence recall task existed. Lastly, a one-way ANOVA was conducted to determine whether differences among recall tasks existed within the two groups. The two factors were group (2 levels: normal hearing and CAPD) and memory test (3 levels: number, word list, and sentence). The main effects of group and memory test and the interactions between group and test were examined.

CHAPTER IV

RESULTS

A total of 10 participants were recruited for this study. All ten participants passed a pure tone hearing screening (ASHA, 2010). The individuals serving in the control group passed the CAPD screening battery, therefore ruling out any diagnosis of CAPD. Despite the fact that all five individuals serving in the CAPD group had a diagnosis of CAPD assigned by an ASHA certified audiologist, only three of these five individuals failed the CAPD screening battery administered to confirm their diagnosis. All individuals participated in the study. The data consisted of scores from the three different tasks described in the previous chapter (word, digit, and sentence recall).

The data from these tasks was analyzed in two separate analyses. The first analysis considered possible differences within tasks across groups. The second analysis considered possible differences between tasks within groups. The digit recall tasks and sentence recall tasks are subtests of a standardized test and therefore yield both raw and standardized scores. The word recall tasks were created specifically for this study and yield only raw, non-standardized scores. Because the format of the word recall tasks was constructed parallel to that of the digit recall tasks, the raw word recall scores can be compared to the raw digit recall scores. Therefore, all comparisons among digit recall and sentence recall scores involve standardized scores, whereas all comparisons among word recall and digit recall scores involve raw scores.

Between Groups Analysis

Table 1 and figure 1 represents the results for the two groups for the recall of word lists with and without a semantic relationship. As the table and figure indicate, the performance of the two groups was very similar on these tasks. Also, the presence or absence of a semantic relationship within the word groups appears not to have significantly affected recall in either group. A repeated measures ANOVA was used to determine whether the differences between the groups and between the two types of word list were significant, and whether there was a significant interaction between group and word list type. The results indicate the following. (1) The effect of group was not significant [$F_{(1, 4)}$ =1.849, *p*=.245]; (2) the effect of word list type was not significant [$F_{(1, 4)}$ =.074, *p*=.799]; and (3) the interaction between group and word list type was also not significant [$F_{(1, 4)}$ =.1.111, *p*=.351].

Table 1. Summary statistics for the semantically related and unrelated word recall tasks across both groups.

Task	**CAPD**			**Control**		
	Mean	S.D.	Range	Mean	S.D.	Range
Word						
Related	6.20	1.095	5-8	6.60	.894	6-8
Unrelated	6.00	1.414	5-8	5.40	1.140	4-7

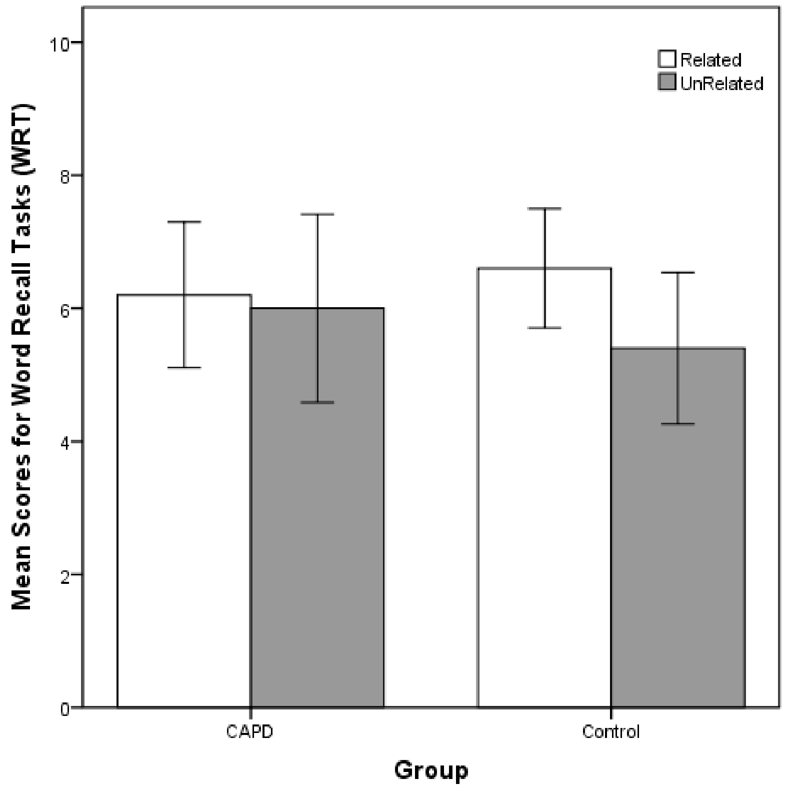

Figure 1. Mean scores and standard deviations for semantically related and unrelated word recall tasks. Error bars indicate +/- 1 standard deviation.

Table 2 and figure 2 represents the results for the two groups for forward, reverse, and total score on digit recall tasks. As the table and figure indicate, the performance of the two groups was similar on these tasks. A repeated measures ANOVA was used to determine whether the differences between groups and between the two types of digit tasks were significant, and whether there was a significant interaction between group and digit list type. The results indicate the following: (1) The effect of group was not significant [$F_{(1, 4)}$ =6.377, p=.065]; (2) the effect of digit task type was not significant [$F_{(2, 3)}$ =1.771, p=.311]; and there was no interaction between group and digit task [$F_{(2, 3)}$ =.000, p=1.00].

Table 2. Summary statistics for the forward and reverse digit recall tasks across both groups.

Task	CAPD			Control		
	Mean	S.D.	Range	Mean	S.D.	Range
Digit						
Forward	8.80	3.347	4-12	11.40	1.817	9-14
Reverse	7.80	1.483	6-10	10.40	2.074	9-13
Total	8.80	2.280	9-14	11.40	1.517	10-13

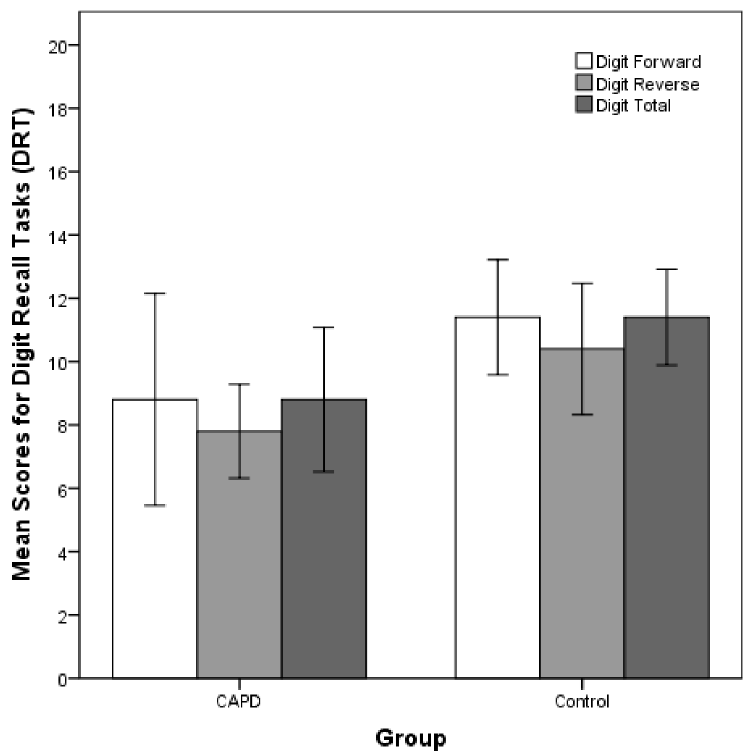

Figure 2. Mean scores and standard deviations of the forward, reverse, and total recall of digits. Error bars indicate +/- 1 standard deviation.

Table 3 and figure 3 represents results for the two groups for the sentence recall task. As the table and figure indicate, the performance of the two groups appeared to differ on this task. A univariate general linear model ANOVA was used to determine whether the difference between the groups was significant. Results indicated that the difference between groups was significant [$F_{(1, 8)}$ =5.554, p=.046].

Table 3. Summary statistics for the sentence recall task across both groups.

Task	**CAPD**			**Control**		
	Mean	S.D.	Range	Mean	S.D.	Range
Sentence	7.80	3.114	5-13	11.60	1.817	9-14

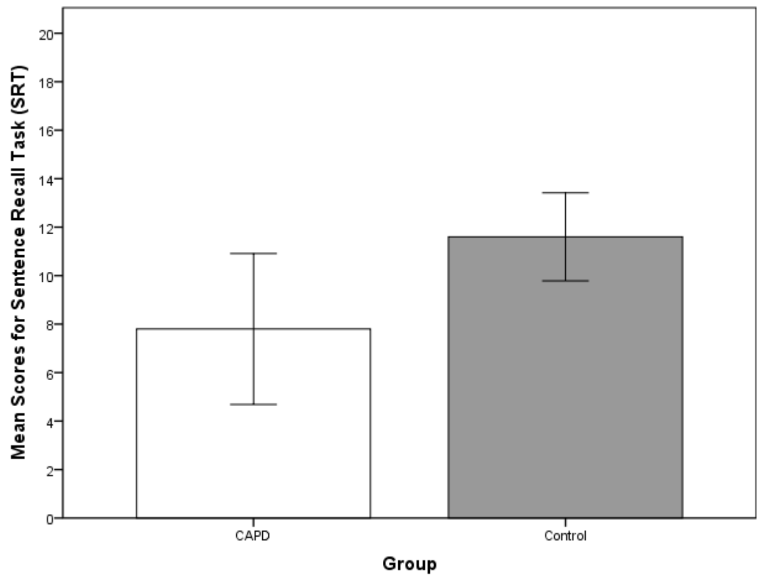

Figure 3. Mean scores and standard deviations for the sentence recall task. Error bars show +/- 1 standard deviation.

Within Groups Analysis

Table 4 and figure 4 represents the results for the forward and reverse recall of digits and recall of word lists with and without as semantic relationship within the CAPD group. As the table and figure indicate, the performance of the individuals with CAPD was similar across the related word, unrelated word, and forward digit recall tasks; however, the mean of the reverse digit recall task was only about half that of the other three recall tasks. A one way ANOVA was used to determine whether the latter task was significantly different from the other three. The test indicated that there was at least one significant difference among the tasks [$F_{(1, 8)}$ =6.889, p=.003]. Tukey's Multiple Comparisons Post Hoc Test indicated that the reverse digit recall task differed from all the other tasks and that no other differences were significant. Table 5 lists the significant pair-wise comparisons.

Table 4. Summary statistics for the word recall tasks and digit recall tasks for the CAPD group.

Task	**CAPD**		
	Mean	S.D.	Range
Related Word Recall Task	6.20	1.095	5-8
Unrelated Word Recall Task	6.00	1.414	5-8
Digit Forward Recall	6.8	2.16	4-10
Digit Reverse Recall	3.0	0.707	2-4

Table 5. Statistically significant differences between digit recall tasks and word recall tasks for the CAPD group.

Task 1	**Task 2**	**Significance**
Reverse Digit Recall	Related Word Recall	.014
Reverse Digit Recall	Unrelated Word Recall	.022
Reverse Digit Recall	Forward Digit Recall	.004

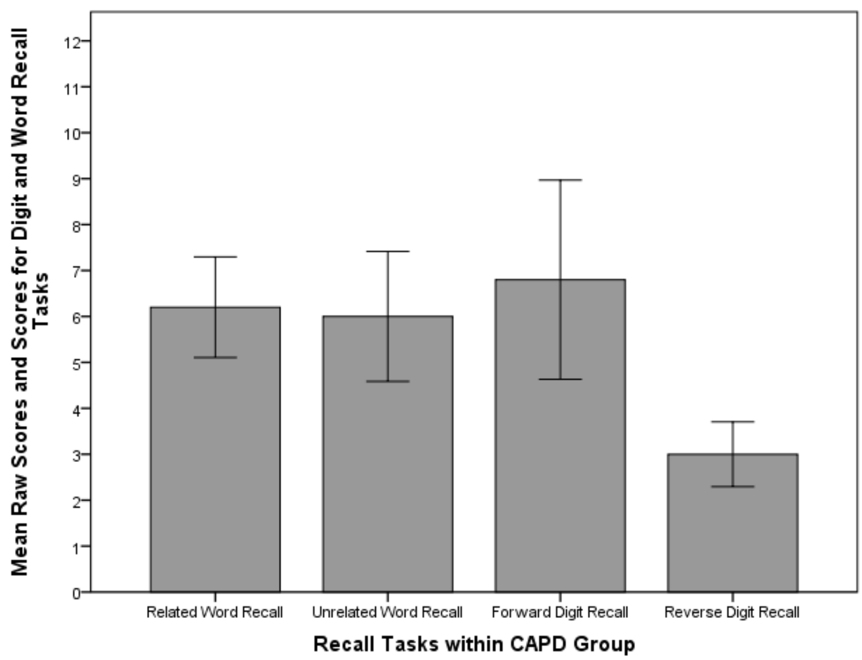

Figure 4. Mean level scores and standard deviations for word recall tasks and digit recall tasks for the CAPD group. Error bars show +/- 1 standard deviation.

Table 6 and figure 5 represents the results for the recall of digits and word lists with and without a semantic relationship within the control group. As the table and figure indicate, control group recall was highest for forward digit recall but did not appear to vary greatly across the other tasks. A oneway ANOVA was used to determine whether significant differences existed among the tasks within the control group. The test indicated that there was at least one significant difference among the tasks [$F_{(1, 8)} = 18.78$, *p*=.000]. Tukey's Multiple Comparisons Post Hoc Test indicated that significant differences exist among the following tasks: (1) forward digit recall differed from all other conditions, and (2) reverse digit recall differed from related word recall. Table 7 lists the significant pair-wise comparisons.

Table 6. Summary statistics for the word recall tasks and digit recall tasks for the control group.

Task	**Control**		
	Mean	S.D.	Range
Related Word Recall Task	6.60	0.894	6-8
Unrelated Word Recall Task	5.40	1.140	4-7
Digit Forward Recall	9.4	1.14	8-11
Digit Reverse Recall	4.6	1.14	3-6

Table 7. Statistically significant differences between digit recall tasks and word recall tasks for the control group.

Task 1	Task 2	Significance
Related Word Recall	Forward Digit Recall	.004
Related Word Recall	Reverse Digit Recall	.045
Unrelated Word Recall	Forward Digit Recall	.000
Digit Forward Recall	Reverse Digit Recall	.000

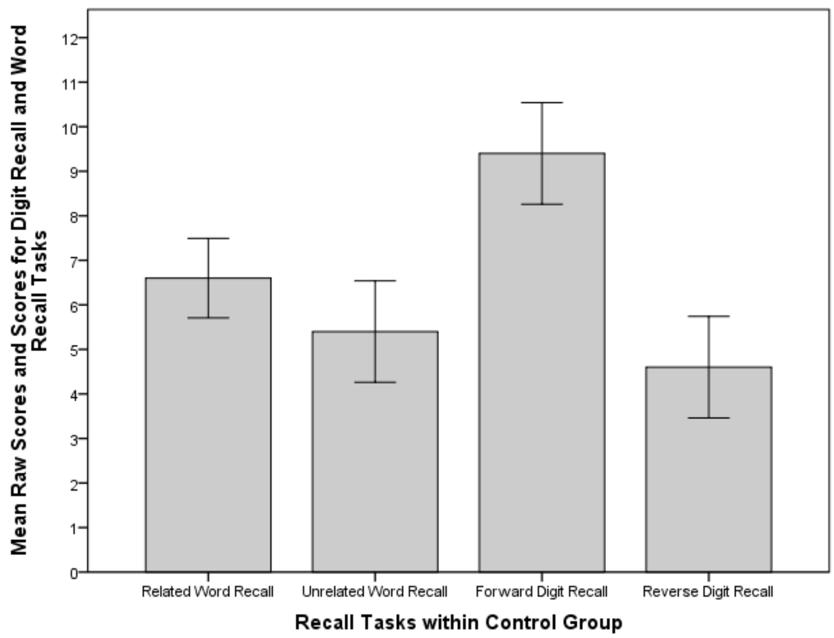

Figure 5. Mean level scores for the word recall tasks and the digit recall tasks for the control group. Error bars show +/- 1 standard deviation.

Table 8 and figure 6 represents a comparison of the digit recall and sentence recall tasks for the within the CAPD group. As the table and figure indicate, the performance of the individuals with CAPD did not appear to vary across the tasks. A one way ANOVA was used to test this claim. The test indicated that there were no differences among the tasks [$F_{(1, 8)}$ = .216, *p*=.808].

Table 8. Summary Statistics for the Digit Recall Task and Sentence Recall Task for the CAPD Group.

Task	**CAPD**		
	Mean	S.D.	Range
Forward Digit Recall	8.80	3.347	4-12
Reverse Digit Recall	7.80	1.483	9-14
Sentence Recall	7.80	3.114	4-13

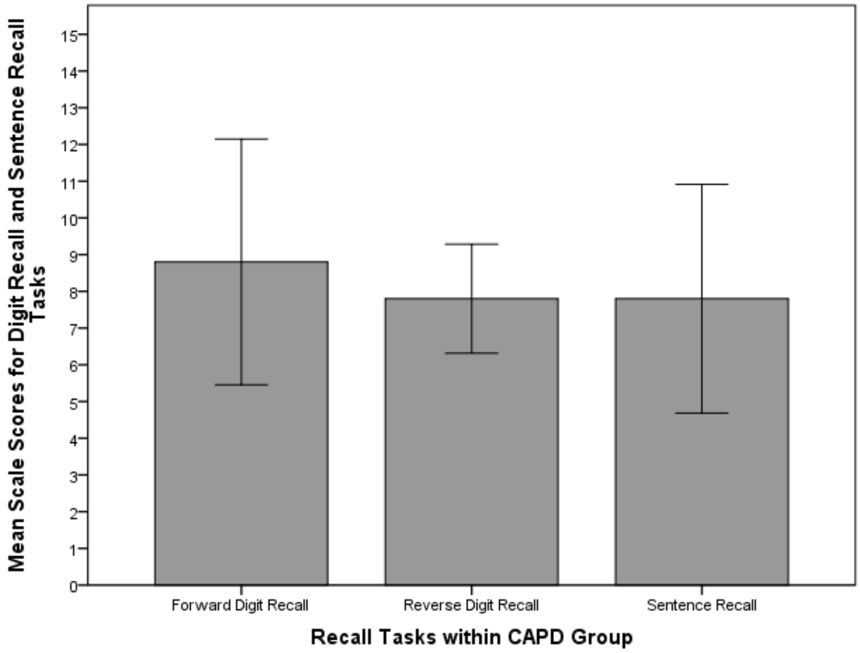

Figure 6. Mean scaled scores and standard deviations for the digit recall tasks and sentence recall task for the CAPD group. Error bars show +/- 1 standard deviation.

Table 9 and figure 7 compare the results for the forward and reverse recall of digits and the recall of sentences within the control group. As the table and figure indicate, the performance of the individuals with control appeared not to vary across tasks. A one way ANOVA was used to support this finding. The test indicated that there were no overall statistically significant differences [$F_{(1, 8)} = .569$, p=.581].

Table 9. Summary statistics for the digit recall tasks and the sentence recall task for the control group.

Task	**Control**		
	Mean	S.D.	Range
Forward Digit Recall	11.40	1.817	9-14
Reverse Digit Recall	10.40	1.517	9-13
Sentence Recall	11.60	1.817	9-14

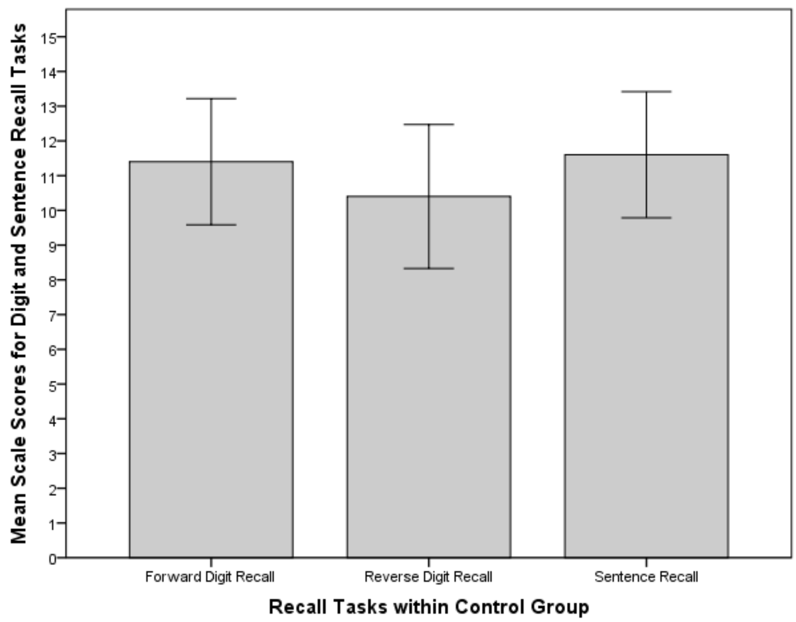

Figure 7. Mean scaled scores and standard deviations for the digit recall tasks and sentence recall task for the control group. Error bars show +/- 1 standard deviation.

CHAPTER V

DISCUSSION

The purpose of this study was to determine whether the auditory recall abilities of typically developing children differed from those of children with a diagnosis of CAPD. Two research questions were developed to compare word, digit, and sentence recall tasks between and within the two groups. The first research question considered if there was a significant difference in performance on recall tasks between the CAPD group and control group. On the word recall tasks, there was no effect of group [$F_{(1, 4)}$ =1.849, p=.245, power= 0.055] or word list type [$F_{(1,4)}$ =.074, p=.799, power=.184], nor was there a significant interaction between group and task list types [$F_{(1,4)}$ =.1.111, p=.351, power= 0.130]. In the case of the digit recall tasks there was no effect of list type [$F_{(2, 3)}$ =1.771, p=.311, power=.0485], nor was there an interaction between group and list type [$F_{(2, 3)}$ =.000, p=.1.00, power= 0.050]. However, the overall effect of group did approach statistical significance [$F_{(1, 4)}$ =6.377, p=.065, power=0.169]. On the sentence recall tasks, there was a significant difference in performance between the two groups [$F_{(1, 8)}$ =5.554, p=.046].

The second research question considered if there was a difference in performance among the different auditory memory task within the CAPD group or the control group. When auditory memory tasks were compared within the CAPD group, results previously presented in tables in Chapter Four indicated that reverse digit recall significantly differed from the other recall tasks, but no other differences were significant. Within the control group, related word recall differed from forward digit recall and reverse digit recall, unrelated recall differed from forward digit recall, and forward digit recall differed from reverse digit recall. It should be noted that findings from this study cannot definitively answer the two research questions because of the low statistical power. The low power is a result of the small sample size in this study.

Relationship to Previous Research

Many researchers have explored the functions of memory in various visual and auditory recall tasks. George Miller (1956) suggests that the span of immediate recall is typically "seven plus or minus two" regardless of the type of unit presented (letter, digit, or word). Results from the forward digit recall tasks indicated that on average individuals without a diagnosis of CAPD recalled 6.2 digits, while individuals with CAPD recalled 5 digits. Results from this study also indicated that on average, the recall of word lists, with and without a semantic relationship, for individuals without a diagnosis of CAPD was 4.6 and 4.2 words respectively, while recall for individuals with CAPD was 4.4 regardless of the word list presented. Therefore, the results from the current study are roughly in agreement with Miller's research, as individuals recalled about five items, regardless of the unit (word or digit). Table 10 represents the average number of units recalled for the digit recall tasks and word recall tasks.

Table 10**.** Number of units recalled for the digit recall tasks and word recall tasks for both groups.

Task	Average Number of Units Recalled for Word and Digit Recall tasks	
	CAPD	**Control**
Forward Digit Recall	5	6.2

Table 10. Cont.

Task	**Average Number of Units Recalled for Word and Digit Recall tasks**	
	CAPD	**Control**
Related Word Recall Task	4.4	4.6
Unrelated Word Recall Task	4.4	4.2

Gillet (1993) has proposed a hierarchy of auditory recall for various types of stimuli. She suggests that complexity increases as one moves from naming concrete objects to numbers, followed by letters, words, and finally sentences. While this study cannot directly compare all three tasks, forward digit recall and word recall tasks were compared and forward digit recall and sentence recall tasks were compared. Both groups appeared to follow Gillet's hierarchy. Individuals within the CAPD group recalled on average slightly more digits than words and preformed slightly higher on the digit recall task than the sentence recall task. Thus, digits were slightly easier to recall than both words and sentences. The results from the individuals without a diagnosis of CAPD were not as supportive of Gillet's hypothesis. This group recalled slightly more digits than words but scored very similarly on both the digit and sentence recall tasks.

Gillet also suggests that the greater the meaning contained in a message is, the better the message is retained and recalled. Results from this study do not support this contention. They did not indicate a significant difference in performance between words lists with or without semantic relationships. Gillet further suggests that the length and complexity of the material or message presented affects one's ability to retain and recall information. Similar to Gillet's suggestions, results from this study indicate that individuals without a diagnosis of CAPD were able to recall sentences of greater length and complexity than individuals with a diagnosis of CAPD. While the sentences used in the study had some degree of meaning, the significant difference between the two groups may be due to the increasing level of complexity and length of the message.

Limitations of this Study

The findings in this study must be viewed as suggestive rather than conclusion. There are several reasons for this. First, the small sample size made it difficult to find statistically significant differences and resulted in low statistical power. Second, it was not hard to recruit typically developing individuals, but it was difficult to find individuals with a clinical diagnosis of CAPD. This is probably because a clinical diagnosis of CAPD typically does not change the intervention or accommodations made for an individual with this diagnosis. As a result, individuals who are suspected of having of CAPD often times are not referred for or do not follow through with formal testing in North Dakota. Because individuals with CAPD were difficult to find for this study, fewer participants were used than what was ideal for the study. Third, some potential candidate for the CAPD group were not included for the following reasons: (1) they did not have an official diagnosis of CAPD, (2) they had another interfering diagnosis (i.e. cognitive delay), or (3) they were not within the age group for the study.

A fourth factor that makes the results less conclusive involves the fact that CAPD is inherently difficult to diagnose with certainty. All the individuals in the control group passed the CAPD screening battery. On the other hand, only three of the five individuals in the CAPD group (all of whom had a diagnosis of CAPD) failed the CAPD screening battery. Therefore, the study could not verify a diagnosis of CAPD for two of the participants. Because of the difficulty finding participants with CAPD, it was decided that all individuals with a diagnosis of CAPD would participate in the study, whether they failed the screening or not. This raises obvious concerns about whether two of the participants in fact suffered from CAPD. The screening battery contained subtests from both the SCAN-3:C and the MAPA. Both of these tools in combination are reliable instruments used in the referral process to separate individuals with a suspected diagnosis of CAPD from typical individuals for further testing (Keith, 2008; Domitz and Schow 2000).

Conclusions of the Study

The following is a summary of the findings of the study.

1. There were no significant differences in the performance of digit recall tasks or word recall tasks between the CAPD group and control group.
2. There was a significant difference in performance on the sentence recall task between the two groups, as the control group performed significantly better than the CAPD group. This finding suggests that as the length and complexity of the stimuli increased, individuals with CAPD did not perform at the level of their same aged peers. This reduced performance is similar to that of children with language disorders, who also perform poorly on sentence recall tasks.
3. The study also considered any differences between standardized digit recall scores and standardized sentence recall scores, as well as word recall raw scores and digit recall raw scores within the CAPD group and the control group. Findings from this study indicated no significant differences between the standard scores on digit recall tasks and sentence recall tasks in either group. However, results indicated that within the CAPD group, reverse digit recall was significantly

poorer than both forward digit recall and both types of word recall. Results for the control group differed from those of the CAPD group as individuals without CAPD preformed significantly better on forward digit recall tasks than other tasks and significantly better on the related word recall task than reverse digit recall task.

APPENDICES

APPENDIX A

SUBJECT RESPONSE BOOKLET

Subject number: ________________________ **Category:** _______________________________

School: __________________________________ **Grade:** ________________________________

Date of testing: -----------------------

Date of birth: _____________

Chronological Age: ____________________

Hearing Screening:

Ear	Level	Frequency		
		1000	2000	4000
RE	20			
LE	20			

Vocabulary pre-screen:

Pass or Fail

APPENDIX B

CENTRAL AUDITORY PROCESSING TESTS

Competing Words–Free Recall (CW–FR)

Circle + for words that are repeated correctly. Circle – for incorrect responses or no response.

Tracks

10 Test Directions

11 Practice Items a & b

12 Test Items

Right Ear			Left Ear		
Practice Items					
a. dig			barn		
b. yard			hill		
Test Items					
1. fell	+	–	pink	+	–
2. coat	+	–	tent	+	–
3. glove	+	–	milk	+	–
4. road	+	–	bake	+	–
5. hope	+	–	room	+	–
6. lake	+	–	ant	+	–
7. tell	+	–	woke	+	–
8. wet	+	–	hand	+	–
9. feel	+	–	sheep	+	–
10. bad	+	–	read	+	–
11. care	+	–	bed	+	–
12. fruit	+	–	bus	+	–
13. nest	+	–	mud	+	–
14. chip	+	–	night	+	–
15. gave	+	–	some	+	–
16. five	+	–	gone	+	–
17. ice	+	–	move	+	–
18. ran	+	–	gold	+	–
19. frog	+	–	mean	+	–
20. soft	+	–	last	+	–

RE Score ____ + LE Score ____ = ____

Filtered Words (FW)

Circle + for words that are repeated correctly. Circle – for incorrect responses or no response.

Tracks	Tracks
13 Test Directions	16 Practice Items–Left Ear
14 Practice Items–Right Ear	17 Test Items–Left Ear
15 Test Items–Right Ear	

Right Ear

Practice Items

a. that

b. white

Test Items

1. hat	+	–	
2. bed	+	–	
3. meet	+	–	
4. on	+	–	
5. weed	+	–	
6. due	+	–	
7. am	+	–	
8. say	+	–	
9. mind	+	–	
10. off	+	–	
11. has	+	–	
12. mile	+	–	
13. must	+	–	
14. bat	+	–	
15. two	+	–	
16. row	+	–	
17. shop	+	–	
18. lie	+	–	
19. when	+	–	
20. wade	+	–	

Left Ear

Practice Items

c. man

d. room

Test Items

21. hose	+	–	
22. grow	+	–	
23. are	+	–	
24. south	+	–	
25. sew	+	–	
26. date	+	–	
27. touch	+	–	
28. hop	+	–	
29. wipe	+	–	
30. truck	+	–	
31. dark	+	–	
32. day	+	–	
33. pot	+	–	
34. save	+	–	
35. best	+	–	
36. right	+	–	
37. fit	+	–	
38. does	+	–	
39. thing	+	–	
40. cry	+	–	

RE Score ______ + LE Score ______ = ______

*Auditory Figure-Ground +8 dB (AFG +8)

Circle + for words that are repeated correctly. Circle – for incorrect responses or no response.

Tracks	Tracks
5 Test Directions	8 Practice Items–Left Ear
6 Practice Items–Right Ear	9 Test Items–Left Ear
7 Test Items–Right Ear	

Right Ear

Practice Items

a. race ______

b. cat ______

Test Items

1. all	+	–	______
2. back	+	–	______
3. end	+	–	______
4. take	+	–	______
5. coat	+	–	______
6. me	+	–	______
7. gray	+	–	______
8. case	+	–	______
9. thick	+	–	______
10. sell	+	–	______
11. next	+	–	______
12. got	+	–	______
13. path	+	–	______
14. bag	+	–	______
15. day	+	–	______
16. feet	+	–	______
17. rain	+	–	______
18. fair	+	–	______
19. waste	+	–	______
20. ball	+	–	______

Left Ear

Practice Items

c. his ______

d. turn ______

Test Items

21. sheep	+	–	______
22. loud	+	–	______
23. hurt	+	–	______
24. pass	+	–	______
25. bee	+	–	______
26. drop	+	–	______
27. quick	+	–	______
28. nest	+	–	______
29. thank	+	–	______
30. sled	+	–	______
31. frog	+	–	______
32. park	+	–	______
33. neck	+	–	______
34. bus	+	–	______
35. shop	+	–	______
36. key	+	–	______
37. fat	+	–	______
38. shoe	+	–	______
39. tall	+	–	______
40. feed	+	–	______

RE Score [ ] + LE Score [ ] = [ ] AFG +8 Total Score

*See note on page 3.

Name:

Binaural Integration Binaural Separation (BIBS)

Dichotic Digits Instructions (15)

Right Ear 1st (16)	Left Ear 1st (17)
□3 □5 □2 / □1 □8 □6	□2 □5 □3 / □8 □6 □9
□4 □1 □8 / □6 □2 □5	□8 □4 □9 / □5 □2 □6
□2 □1 □9 / □5 □4 □8	□9 □1 □2 / □8 □4 □5
□2 □5 □4 / □6 □3 □1	□3 □5 □2 / □1 □4 □6
□5 □4 □8 / □2 □6 □3	□8 □1 □5 / □3 □9 □2
□4 □1 □9 / □3 □2 □6	□9 □1 □4 / □6 □5 □3
□3 □8 □1 / □6 □9 □4	□1 □9 □4 / □6 □3 □2
□2 □9 □6 / □1 □3 □8	□5 □6 □2 / □8 □3 □9
□9 □6 □1 / □4 □8 □3	□9 □4 □6 / □1 □2 □8
□9 □2 □4 / □5 □8 □1	□4 □2 □9 / □6 □8 □5

Right 1st Total _____/60
any order
Left 1st Total ______/60
any order
R/L Total ________/120
any order

Pitch Pattern Instructions: (13)
Binaural (14)

"You try…" ___________

LHHH	__________
HHLL	__________
LHLL	__________
HHLH	__________
HHHL	__________
LHHL	__________
HLLL	__________
LLLH	__________
HLHH	__________
LLHH	__________
HLHL	__________
LHLH	__________
HLLH	__________
LLHL	__________
HHHL	__________
LLLH	__________
HLHH	__________
HHLL	__________
HHLH	__________
LHHH	__________

Total __________/20

APPENDEX C

AUDITORY RECALL TASKS

Number Repetition 1 (NR1, Ages 5–16) *continued*

Forward

Item		Response	Score
1. a.	3–5		1 0
b.	7–2		1 0
2. a.	2–8–6		1 0
b.	6–3–4		1 0
3. a.	6–2–5–8		1 0
b.	2–4–1–7		1 0
4. a.	9–5–1–4–8		1 0
b.	5–8–2–1–6		1 0
5. a.	4–7–8–1–6–3		1 0
b.	7–3–9–8–6–4		1 0
6. a.	6–1–7–4–2–3–8		1 0
b.	9–3–8–6–5–1–2		1 0
7. a.	5–3–8–7–2–1–6–4		1 0
b.	2–4–9–5–7–1–6–3		1 0
8. a.	1–6–4–5–9–7–2–8–3		1 0
b.	4–5–2–3–6–8–9–7–1		1 0
		Forward Raw Score	

Backward

Item		Correct Response	Response	Score
1. a.	3–8	(8–3)		1 0
b.	7–4	(4–7)		1 0
2. a.	4–8–3	(3–8–4)		1 0
b.	3–6–8	(8–6–3)		1 0
3. a.	5–2–9–6	(6–9–2–5)		1 0
b.	8–3–4–9	(9–4–3–8)		1 0
4. a.	4–7–1–5–3	(3–5–1–7–4)		1 0
b.	9–2–7–5–8	(8–5–7–2–9)		1 0
5. a.	1–8–6–9–5–2	(2–5–9–6–8–1)		1 0
b.	3–4–6–9–7–1	(1–7–9–6–4–3)		1 0
6. a.	8–2–5–4–9–3–2	(2–3–9–4–5–2–8)		1 0
b.	4–1–5–8–7–2–9	(9–2–7–8–5–1–4)		1 0
7. a.	6–8–9–5–1–2–6–3	(3–6–2–1–5–9–8–6)		1 0
b.	3–2–1–8–7–5–9–4	(4–9–5–7–8–1–2–3)		1 0
			Backward Raw Score	
			NR1–Total Raw Score	

Word List- Related

Say to the student, "Say these words after me." Then, read each of the items to the student. Provide credit if correct. If words are said correctly but out of order, indicate what order the words were recalled.

*Indicate order with tallies or numbers (i.e. I, II, III... or 1, 2, 3...)

1a. Ball	Bat							
1b. Hot	Cold							
2a. Window	Door	Floor						
2b. Fish	Water	Tank						
3a. Bird	Dog	Cat	Mouse					
3b. Penny	Quarter	Dime	Nickel					
4a. Chair	Table	Couch	Lamp	Desk				
4b. Crayon	Marker	Pen	Pencil	Paper				
5a. Apple	Pear	Cherry	Grape	Orange	Banana			
5b. Bus	Truck	Van	Wagon	Car	Bike			
6a. Shirt	Pants	Shoes	Socks	Hat	Belt	Sweater		
6b. Dirt	Seed	Flower	Grow	Petals	Water	Stem		
7a. Spoon	Plate	Glass	Knife	Cup	Fork	Bowl	Napkin	
7b. Pail	Sand	Ocean	Shovel	Shell	Castel	Crab	Boat	
8a. Purple	Blue	Red	Pink	Green	Black	Yellow	Orange	White
8b. Knee	Elbow	Head	Foot	Hand	Ear	Arm	Eyes	Leg

#	+ /-
1a.	
1b.	
2a.	
2b.	
3a.	
3b.	
4a.	
4b.	
5a.	
5b.	
6a.	
6b.	
7a.	
7b.	
8a.	
8b.	

Word List- Unrelated

Say to the student, "Say these words after me." Then, read each of the items to the student. Provide credit if correct. If words are said correctly but out of order, indicate what order the words were recalled.

*Indicate order with tallies or numbers (i.e. I, II, III... or 1, 2, 3...)

1a. Cane	Ship							
1b. Bat	Car							
2a. Ham	Pan	Vet						
2b. Sun	Town	Face						
3a. Goat	Hand	Rake	Toe					
3b. Fan	Chair	Snow	Knife					
4a. Park	Dime	Earth	Game	Jeep				
4b. Rice	Snail	Ear	Bear	Five				
5a. King	Post	Dog	Shoe	Tooth	Worm			
5b. Wall	Farm	Bun	Guard	Coat	Gate			
6a. Bug	Dress	Book	Leaf	Clock	Door	Big		
6b. Read	Hair	Grass	Coat	Top	Smile	Color		
7a. Stripe	Lake	Arm	Pig	Song	Horn	Grill	Frog	
7b. Chair	Word	Deck	Ball	Needle	Sign	Oil	Drum	
8a. Friend	Shirt	Tent	Hour	Plant	Talk	Cold	Lamp	Wheel
8b. Scream	Mile	Purse	Stick	Room	Cat	Drink	Bus	Soap

#	+/-
1a.	
1b.	
2a.	
2b.	
3a.	
3b.	
4a.	
4b.	
5a.	
5b.	
6a.	
6b.	
7a.	
7b.	
8a.	
8b.	

Recalling Sentences (RS) *continued*

Start	Item	OK	1 Error	2–3 Errors	4+ Errors
5–8	1. The tractor was followed by the bus.	3	2	1	0
	2. Did the girl catch the baseball?	3	2	1	0
	3. Did you remember to bring your lunch?	3	2	1	0
	4. The boy fell and hurt himself.	3	2	1	0
	5. Was the van followed by the ambulance?	3	2	1	0
9–13	6. The rabbit was not put in the cage by the girl.	3	2	1	0
	7. Didn't the boys eat the apples?	3	2	1	0
	8. The big, brown dog ate all of the cat's food.	3	2	1	0
14–21	9. Does anyone know who the new teacher is?	3	2	1	0
	10. The kindergartner cannot cross the street by himself.	3	2	1	0
	11. The play castle was built by the girls and boys.	3	2	1	0
	12. Because tomorrow is Saturday, we can stay up late tonight.	3	2	1	0
	13. The book was not returned to the library by the teacher.	3	2	1	0
	14. The coach could not find the uniforms that the team wore last year.	3	2	1	0
	15. The girl stopped to buy some milk, even though she was late for class.	3	2	1	0
	16. My mother is the nurse who works in the community clinic.	3	2	1	0
	17. The boy bought a book for his friend who likes short stories.	3	2	1	0
	18. If the rain doesn't stop before noon, the field trip will have to be canceled.	3	2	1	0
	19. The computers and printers were donated by the school board.	3	2	1	0
	20. The student who won the award at the art show was very excited.	3	2	1	0
	21. The class that sells the most tickets to the dance will win a prize.	3	2	1	0
	22. After the students had finished the book, the teacher asked them to write a report.	3	2	1	0
	23. Coach gave the trophy to the team that won the track meet on Saturday.	3	2	1	0
	24. The students collected and repaired the toys, and sold them at the fair.	3	2	1	0
	Column Subtotals				

Recalling Sentences (RS) *continued*

	OK	1 Error	2–3 Errors	4+ Errors
25. Today we must have lunch early, go to the library, and finish our art projects.	3	2	1	0
26. When the students finished studying, they decided to get something to eat before going home.	3	2	1	0
27. The librarian has twelve new eighth-grade science books reserved for us.	3	2	1	0
28. If we had gone straight home after the game, we would not have missed our curfew.	3	2	1	0
29. Before they walked across the stage for graduation, the students lined up in alphabetical order.	3	2	1	0
30. If I don't have to work this weekend, I should be able to complete my research paper for English.	3	2	1	0
31. Before the students were dismissed for lunch, they were told by the teacher to turn in their assignments.	3	2	1	0
32. The math teacher sorted, labeled, boxed, and delivered the calculators.	3	2	1	0
Column Subtotals				
Sum of Column Subtotals = Raw Score				

REFERENCES

American Academy of Audiology (2010). American academy of audiology, clinical practice guidelines: diagnosis, treatment, and management of children and adults with central auditory processing disorder. (2010, August 24). , 4-7.

American Speech-Language-Hearing Association. (2005). *(Central) Auditory Processing Disorders* [Technical Report]. Available from www.asha.org/policy.

Bellis, T. J. (2003). Assessment and Management of Central Auditory Processing Disorders In the Educational Setting From Science to Practice (2 ed., pp. 1-424). Clifton Park, NY: Thompson Delmar Learning.

Chermak, G. D., & Musiek, F. E. (1997). Central Auditory Processing Disorders (pp. 1-277). San Diego, CA: Singular Publishing Group INC.

Eysench, M. W. (2001). *Principles of cognitive psychology* (2 ed., p. XX). Hove, United Kingdom: Psychology Press.

Gillet, P. (1993). Auditory Processing (pp. 5-91). Novat, CA: Academic Therapy.

Goldstein, B. E. (2008). Cognitive Psychology Connecting Mind, Research, and Everyday Experience (2 ed., pp. 57-61). Belmont, CA: Thomson Wadsworth.

Keith, R. W. (2009). SCAN-3:C Test for auditory processing disorder for children.

Lasky, E. Z., & Katz, J. (Eds.). (1983). *Central Auditory Processing Disorders Problems of Speech, Language, and Learning* (pp. 4-43). Baltimore, MD: University Park Press.

McAdams, S., & Bigand, E. (1993). *Thinking in sound: the cognitive psychology of human audition* (p. XX). Oxford, United Kingdom: Oxford University Press.

Purser, H., & Jarrold, C. (2010). Short- and long-term memory contributions to immediate serial recognition: Evidence from serial position effects. The Quarterly Journal of Experimental Psychology, 63(4), 679-693. Retrieved November 3, 2011

Sloan, C. (1986). *Treating auditory processing difficulties in children*. San Diego, CA: College-Hill Press.

Schow, R. L., & Nerbonne, M. A. (2007). Introductions to Audiologic Rehabilitation (5 ed., pp. 290-297). Boston, MA: Pearson.

Schow, R. L., Seikel, A., Brockett, J. E., & Whitaker, M. M. (2007). Multiple auditory processing assessment. St. Louis, MO: Auditec.

Semel, E., Wiig, E. H., & Secord, W. (2003). Clinical evaluation of language fundamentals (4th ed.).

Calvin College Hekman Library openURL resolver

Shipley, K. G., & McAfee, J. G. (2009). *Assessment in speech-language pathology: a resource manual* (4th ed., p. XX). Clifton Park, NY: Delmar Cengage Learning.

Weiten, . (2007). Psychology Briefer Version (7th ed., pp. 205-211). Mason, OH: Thomson WadswortH.